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ABSTRACT

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To avoid high surface temperatures, some 75-thousand coho salmon (Oncorhynchus kisutch) fingerlings were released below the thermocline of a lake into 10°C water at 12 m below the surface via a pipe laid along the bottom. Some 14-thousand coho smolts were produced from the lake and diverted past a series of damaging cascades 70 m in height via a 700-m long 6.4-cm dia. plastic pipe. Both techniques were successful and have significant potential in the rearing of salmonids in habitats that would otherwise be unavailable for such use.

RÉSUMÉ

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Pour leur permettre d'éviter les fortes températures de surface, on a libéré quelque 75 000 petits tacons de saumon coho (Oncorhynchus kisutch) au-dessous de la thermocline d'un lac, dans de l'eau à 10°C, 12 m au-dessous de la surface, grâce à un tuyau installé sur le fond. Environ 14 000 smolts de cohos ont été produits dans le lac et, grâce à un tuyau de plastique de 6,4 cm de diamètre et de 700 m de longueur, ils ont pu contourner des cascades dangereuses de 70 m de hauteur. Ces deux techniques ont donné de bons résultats et présentent un net potential pour l'élevage de salmonidés dans des habitats où cela serait impossible dans des conditions naturelles.

INTRODUCTION

In our investigations of the colonization of habitats inaccessible to anadromous coho, problems have arisen of how to guide large numbers of fish around different types of physical barriers that may be present during different phases of their life-history. Our research is, in part, directed at increasing the probability of success of such introductions. This report describes how we successfully passed fingerlings through excessively warm surface waters of a lake and smolts around a 700-m stretch of cascades having a vertical drop of about 70 m in several abrupt falls, often among sharp rocks and without cushioning plunge pools.

The techniques were developed and tested at a small lake in the Koksilah River watershed, first colonized in 1985 with coho fry obtained from various locations in the adjacent Cowichan River [BC Ministry of Environment and Parks Catalogue No. 92-4800]. Both rivers are located in the south-eastern part of Vancouver Island, B.C., Canada. The lake, Grant Lake, (Cat. No. 92-4800-020-500) is perched at some 70 m above the main river, drains an area of approximately 7.9 km^2, is 52 hectares in area, has a maximum depth of 40.5 m, an average depth not less than 20 m, and develops a clearly defined thermocline early in the summer. It contains substantial populations of self-perpetuating rainbow (Salmo gairdneri) and cutthroat trout (S. clarki).

Unfortunately, we were not in a position to execute comparative testing of either technique, i.e. releasing two groups of selectively marked fish and comparing their growth and survival to, at least, the smolt stage. However, the single tests can demonstrate whether or not transport by these methods is feasible and if there are immediate negative effects associated with forcing small fish through a pipe to an unaccustomed depth in a lake or transporting them over a long distance with a 1 in 10 incline. Not having any form of experimental control precludes evaluation of the tests in terms of actual improvements achieved during these tests.

I. RELEASE BELOW THE THERMOCLINE

During our first introduction of coho in July 1985 it was noted that the fry were severely stressed when they were transferred from the transport tank, at 12 C, and entered the lake water, at about 20 C. Fish darted about both horizontally and vertically before settling down, and some deaths occurred. Mortality was not extensive, however, as indicated by subsequent

excellent growth and survival to the smolt stage (Bams, unpublished data).

In 1986 the lake surface warmed very quickly and the fish would have had to be released at an even greater temperature differential. We decided to attempt a release below the thermocline into water matching the temperature of the rearing and transport water and to rely on the fish's ability to choose their own conditions at their own speed. Much preference testing in the laboratory with, e.g. salinity and temperature, has demonstrated such behaviour to occur spontaneously (Baggerman 1960; Coutant 1977).

This idea undoubtedly has occurred to many a field-biologist before, and I was able to locate one published report (Sharpe 1961) of a successful (no obvious immediate stress or mortality) rainbow trout plant into a stratified impoundment. Here scuba-equipped divers took the fish down to the appropriate depth at 4 m in plastic bags. Some fish swam out of the opened bags voluntarily, others had to be forced out. The fish appeared confused and swam in gradually widening circles around the diver, slowly working their way upwards and outwards until they disappeared from view.

Equipment

At lake-side we erected an open wooden box, measuring about 61 by 122 cm by 61 cm high, equipped with fish-proof overflow screens in the long sides and having a 10-cm dia flexible outlet-hose (corrugated black plastic "Big-O" pipe) running out into the lake along the bottom for about 20 m to a depth of 12 m. This location was well below the thermocline and water temperature here was 10 C, the same as that of the hatchery rearing ponds and the transport water. Water was pumped into the box by means of a portable gasoline-powered fire pump located on a floating dock. The pump had its 6.4 cm dia. intake at the 10 C level and delivered about 150 Lpm into the box.

Scuba divers adjusted the intake and outlet levels, guided by in situ temperature measurements and the topography of the lake bottom. In a routine application the divers could be dispensed with and the necessary observations obtained from a sounding line equipped with a thermister temperature probe. Alternatively, the temperature of the water emerging from the pump could guide the level of the intake. Under some circumstances a lake may develop a dissolved oxygen (DO) gradient associated with the thermocline. Testing DO levels will then be necessary to ensure adequacy of water quality.

On the 31st of July, at about mid-day, fish were scooped from the transport tank with small dipnets, about 45

minutes after arrival. They were released immediately in front of the outlet pipe, and proceeded down the pipe immediately without undue hesitation or observable fright response.

Two groups of fish totalling about 76-thousand were released about 40 minutes apart. The first consisted of hatchery-reared fingerlings, averaging just over 5 g. These fish had been reared at the hatchery from eggs and were fully acclimated to the consistent ambient hatchery temperatures running at 10.2 C at the time of transport. The second group had been "salvaged" from drying natural stream habitats in the Koksilah system during the previous week or two (Burns et al. 1987). They were held and fed at the hatchery under conditions identical to the first group and averaged just over 2 g. The two groups derived from essentially the same, mixed, Cowichan River brood stock and were marked differentially by excision of a ventral fin for recognition upon subsequent recapture.

Observations

The divers observed the fish as they emerged from the pipe. There were some similarities and some differences in the behavior of the fish of the two groups. On emerging from the pipe the hatchery fish were reluctant to move; they largely settled on the bottom near the pipe and moved only short distances at a time. There was no movement directly upward (away from the bottom) or down into deeper water. When the fish did start to move they worked gradually and slowly along the bottom up towards the shore following submerged objects such as the discharge pipe and waterlogged tree stems and branches lying on the bottom. No fish were observed from the shore for at least 45 minutes and once they did appear they remained at about 2-m depth below the floating dock and the numbers were very slow in building up.

The salvaged fish, which had been in the hatchery troughs for only a short time, behaved quite differently. Upon emergence from the pipe they did not settle down, but started their up-migration immediately. They, too, did not lose contact with the bottom or swim into deeper water but moved in a fairly narrow, shallow band in an essentially direct line towards the shore. They could be seen from the dock within 15 minutes and some fish continued immediately into the shallow water right up against the shore among the water weeds and willow roots. Once inshore they spread in both directions staying in the shallows, actively foraging and gradually dispersing.

This dispersal was in marked contrast to that of the hatchery fish, which was much slower, did not reach into the very shallow water and took hours to cover the same distance. At no time were the fish of either group visibly stressed, and no

mortalities were observed. After about 3 hours fish were spread out along the shore for some 50 to 60 m in both directions from the release site in a band about 6 m wide. They were foraging at and near the surface and continued to disperse. By the next day local densities were greatly reduced and fish were seen several hundred meters away from the release site. Coho fingerlings in lakes are known generally to prefer the littoral area (e.g. Swales et al. 1988).

Clearly, fish with different rearing histories controlled their rate of ascent differently and, one assumes, appropriately to their physiological and behavioural needs and limitations. The lack of any "panic" dispersal immediately following emergence from the pipe was particularly encouraging. Releasing the fish at the bottom rather than in mid-water clearly facilitated their orientation and guiding to the initial preferred habitat, the inshore shallows. Survival and growth subsequent to release were excellent in both groups (Bams, unpublished data) and the technique holds promise for situations where a temperature barrier might otherwise prevent or jeopardize a successful fry release.

II. BYPASS AROUND CATARACTS

The first smolt run, in 1986, demonstrated that fish of a major proportion of the run arrived at the bottom of the series of falls in damaged condition. Scale loss of from 5 to over 50% to the sides of the fish was universal and thousands of fish had interrupted their downstream migration long enough to have their descaled sides and often parts of their heads and fins covered with fungus. The fish were "clean" upon first leaving the lake. Fish held up in the creek so long that several mink moved into the area and killed them by the dozens, as witnessed by rows of fish heads found lying on banks and on logs in the creek. Many dead fish were also observed in back-eddies and some pools, all badly damaged and usually heavily infected with the fungus Saprolegnia. Some protective measure was clearly needed and we decided to build a simple by-pass around the problem area and evaluate its effectiveness on the following brood-year.

The main literature on fish-bypass structures, e.g., Bell 1972, 1981, 1986; Osborn and Powers 1985, deals primarily with large structures (especially around power dams), and the prevention of young fish to enter various intakes. It is clear that young fish can be successfully diverted with mechanical screens, and moved through open and closed conduits of considerable length. Further, substantial pressure differences and high water velocities have been demonstrated to cause very

little harm to sensitive smolts when handled with care, e.g., Schoeneman 1959.

Equipment

Since the outlet of the lake was equipped with a low concrete dam it was a simple matter to erect a low fence on top of it directing the fish through a gap in the centre into a stepped-down trough leading into the transport pipe. The trough was 61 cm wide, 488 cm long, had solid sides to a depth of 14 cm and screen for an additional 30 cm to allow excess water to flow from the trough back into the creek. It had a cover to keep out predators. Near the downstream end we installed a vertical baffle with a 5 by 5 cm hole, which controlled the amount of water reaching the outlet end and forced the variable overflow through the side screens. By manipulating the height of the water in the outlet section between the baffle and the pipe inlet we could control the amount of water running down the pipe with surprising consistency.

Later in the season, when lake surface temperatures went above 20 C, fish were reluctant to go over the concrete lip but they were seen to school in front of the dam, close to the bottom. We installed a wooden chute, about 15 by 30 cm in cross section, down the front of the dam with its intake near the dam's base and the outlet projecting over the lip. The fish used the chute immediately and went over the top without further evidence of undesirable delays.

The bypass pipe was built from 6 m sections of white, translucent 6.4 cm dia. PVC pipe designed to be joined by inserting one section into the bell shaped end of the next one. They were held together with stainless steel wire and screw clamps. We used the white plastic material to reduce heat gain in sections exposed to full sunlight. Total pipe length was 707 m over a vertical drop of 70 m. The pipe terminated just above the water surface in a large, baffled, and marquisette-lined box. Fish were held there and in an additional, similar box located in the stream until they were counted, sampled, and coded-wire nose-tagged, generally once every 3 to 5 days.

Observations

Initial flow was established at approximately 55 Lpm, but we subsequently reduced this to about 34 Lpm. At this latter flow retention time in the pipe was about 6 minutes and fish arrived in the box in excellent shape, without any visible agitation or damage. Very few fish were observed in the holding boxes with any scale loss; the few that did are believed to have damaged themselves in the boxes by jumping or trying to squeeze

through partitions inside the boxes. The pipe quickly developed a very slippery inside surface, presumably due to bacterial/algal growth, which likely contributed to the lack of abrasion noted on the fish. A major improvement had been accomplished compared with events in the previous year.

Temperature gain was negligible (less than 2 F) even on warm sunny days. We were also concerned about possible gas supersaturation, given the considerable height differential. Measurements with a Novatech model 300B tensionometer showed a gain of only from 2 to 5% total gas saturation at the lowest flows used, and, hence, there was no danger to the fish. We checked the pipe for flow patterns by hefting it and by listening for the rush of water along its path. It was clear that although there were some relatively short sections where the pipe ran full, along most of its length this was not the case and the pipe ran less than half volume, thus equilibrating the gas pressures continually. At the lower flow, water velocity at full pipe was calculated to be 1.2 m/minute, i.e., 20 cm/second, whereas the average velocity was 11.8 m/minute, or 196 cm/second. This latter flow corresponds to 10% of full pipe or a depth of only 10 mm of water. At certain levels of flow minor surging would occur. At all flows some air would get entrained and was continually spewed out the end of the pipe. This too did not affect the performance and fish were never observed to be stressed or in any way adversely affected by their enforced passage.

IMPLICATIONS FOR MANAGEMENT

It proved quite feasible to release coho fry into a lake, at considerable depth, well below a thermocline, in water having the same temperature as the fish had been reared in. Release near the bottom facilitated orientation and the fish reached the shallow shore waters in their own time and at their own speed without visible signs of stress or other difficulty associated with depth or temperature differentials.

In the bypass test we were quite successful in directing coho smolts around a series of damaging cascades, transporting them 700 m horizontally and 70 m vertically in about 6 minutes, again without visible signs of stress or damage induced by the procedure.

Both techniques have significant potential in the rearing of anadromous salmonids in habitats otherwise unavailable for such use.

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